

P. Polgar
M. M. Roy
T. H. Yeh

A Drive Scheme for the GaAs-Si Light-Activated Switch

The development of a GaAs-Si light-activated switch, designed to serve as a building block in an integrated electronic gating system (multiplexor), has been reported.¹⁻³ It was found that the usefulness of the gating system could be greatly amplified if a simple drive scheme could be designed to operate compatibly with it. Such a drive scheme has been developed, and is briefly described here. It possesses both simplicity and a high degree of compatibility, since its principal components are the same (GaAs light emitting diode and double-emitter silicon transistor) as those which make up the light-activated switch. Incorporated in an integrated package, the drive scheme has the advantages of minimized power requirements, a minimum number of components, and increased reliability (through reduction of the requirement for interconnections).

The drive scheme or "latching" circuit is shown in Fig. 1, while Fig. 2 shows a cross section of the device itself. The application of a forward bias to the emitter of T_L will turn the transistor on and, with an appropriate choice of V_{ce} , current sufficient to cause light emission

will pass through the diode D_L . The light from the diode serves as a base drive for T_L and will keep the transistor on even after the external bias is removed. Grounding the emitter base junction, or applying a reverse bias to it, will turn T_L off. The current path is then broken and light emission ceases.

The major requirement for effective latching is that

Figure 2 (a) Photograph of device; (b) cross-section.

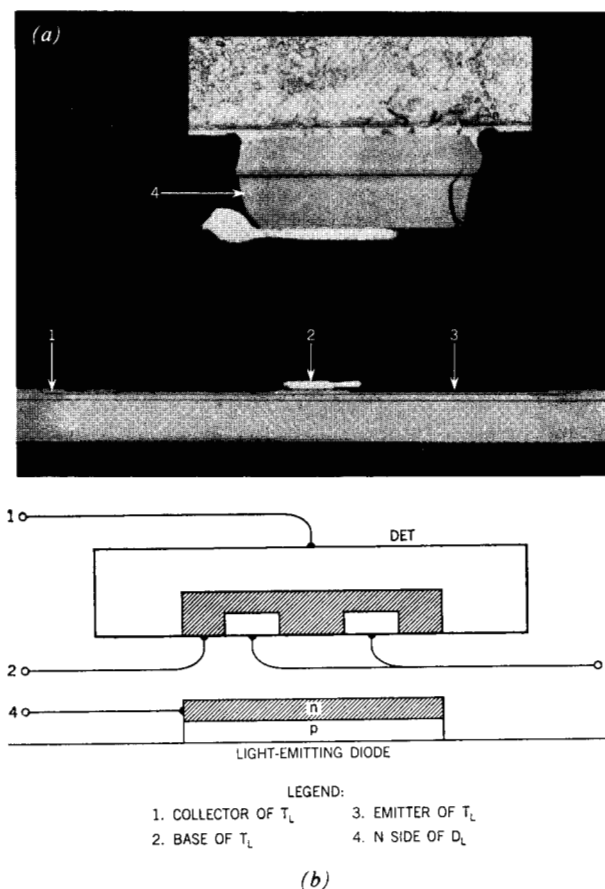
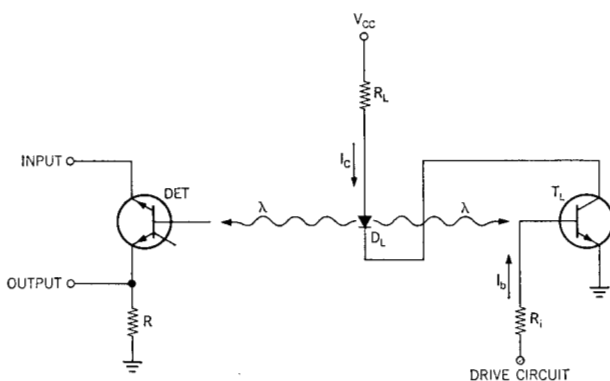


Figure 1 Schematic of drive circuit and driven DET.



the combination of D_L and T_L must possess a current gain equal to, or greater than, unity. Together with a double-emitter transistor (DET), this latching arrangement is shown in Fig. 1. When D_L is passing current, the light illuminates not only T_L but the DET also, and the latter is turned on. Turning off the latching circuit will turn off the DET.

Several latches have been built using two types of drive transistors: high β double-diffused (Type 1), and lower β single-diffused (Type 2). The double-diffused devices were made by diffusing boron, then phosphorus into an epitaxial n on n^+ silicon wafer, whereas the single-diffused devices were made by diffusing phosphorus into an epitaxial p on n^+ silicon wafer. The latches were carefully studied to determine the necessary conditions for latching. The minimum latching levels of V_{ce} and I_b have been determined and the results are summarized in Table 1.⁴

In addition, the $I_c - V_c$ characteristics, with I_b as a parameter, have been determined (Figs. 3a and 4a) for the latching transistor T_L . Using these, I_b vs I_c curves have been plotted in Figs. 3b and 4b. Superimposed on these Figures are the I_{bL} (effective base current generated by light) vs I_c (current through D_L) curves. The points of intersection establish the values of I_b , emitter-base forward bias, necessary to initiate and sustain latching. The values calculated from the plots are in good agreement with experimental results and the analysis seems adequate to a first-order approximation. Table 2 shows a comparison between experimental and calculated values for a unit from the double-diffused run.

The drive scheme described here is one of several possible applications, using the light-activated switch or its component parts, which lend themselves in their present form or with slight changes to several areas in the field of optoelectronic devices.

Figure 3 Operating characteristics, Type 1 latching transistor: (a) I_c vs V_c ; (b) I_b vs I_c .

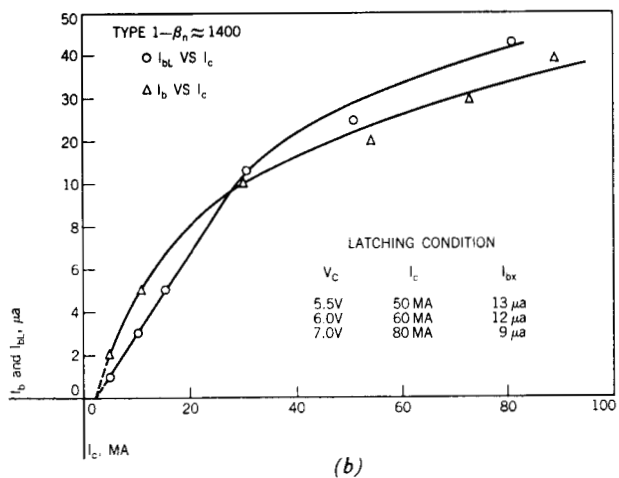
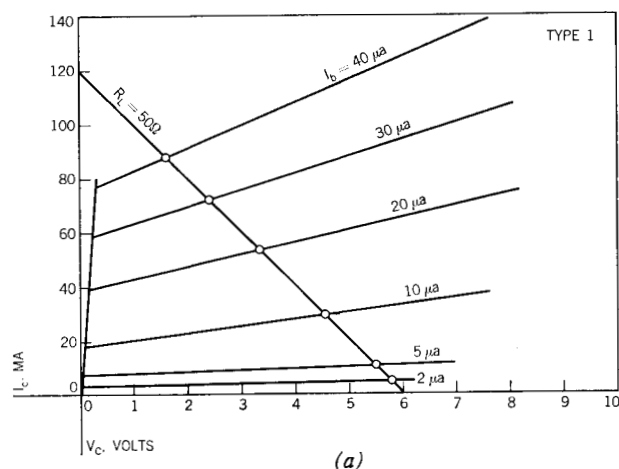


Figure 4 Operating characteristics, Type 2 latching transistor: (a) I_c vs V_c ; (b) I_b vs I_c .

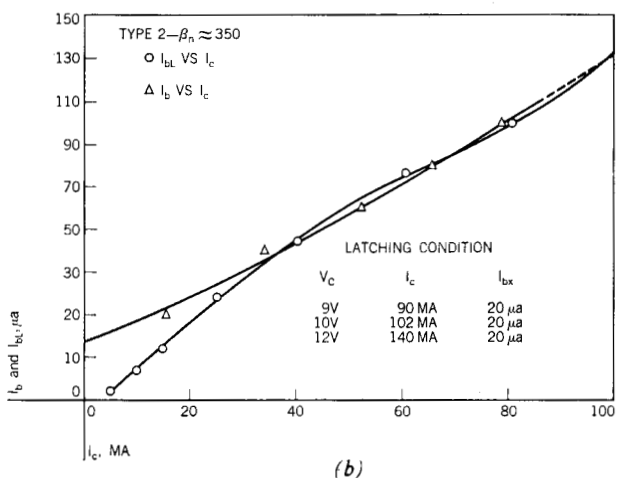
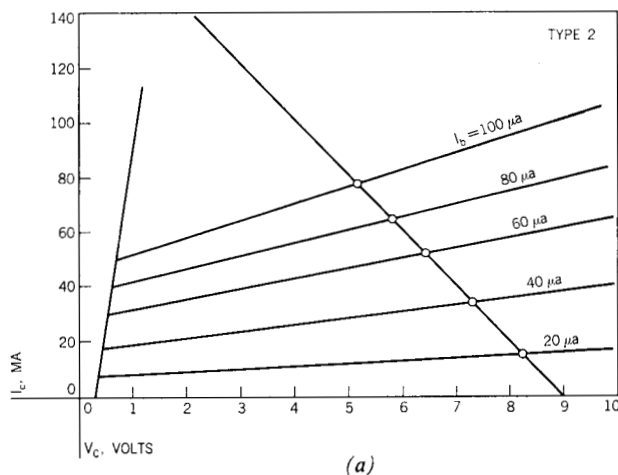


Table 1 Latching conditions

Device	V_{cc} (V)	I_b (μ A)	β_n at $I_b = 0.2$ mA	I_c (mA)	R_{CE} (Ω)
a	5.5	13	1400	50	8
(Type 1)	6.0	12	1400	60	6
	7.0	9	1400	80	6
b	7.5	20	1200	70	9
(Type 1)	10.0	16	1200	115	8
c	12.0	7	980	140	8
(Type 1)	14.0	6	980	170	8
d	17.0	21	500	205	8
(Type 1)	19.0	19	500	230	8
e	9.0	20	350	90	—
(Type 2)	10.0	20	350	102	—
	12.0	20	350	140	—
f	12	26	240	120	14
(Type 2)	13	26	240	140	13.5

V_{cc} = power supply voltage.

I_b = emitter base forward bias necessary to initiate latching.

β_n = forward β of T_L .

I_c = current flowing through T_L when latched.

R_{CE} = collector-emitter impedance measured as a function of I_D (diode current).

Type 1 = double-diffused DET

Type 2 = single-diffused DET

Table 2 Calculated latching conditions compared with measured results.

Experimental latching point		Calculated latching point
I_b	13 μ A	15 μ A
I_c	50 mA	39 mA
V_{cc}	5.5 V	3.5 V

Acknowledgments

The authors would like to thank Dr. W. A. Pieczonka for suggesting the approach of the drive scheme and Dr. E. S. Wajda for valuable discussions during the study.

References and footnotes

1. W. A. Pieczonka, T. H. Yeh, P. Polgar and M. M. Roy, "GaAs-Si Photon Activated Switch," *IEEE Electron Devices Meeting*, October 1964.
2. "Integrated Electronic Gating System for Multiplexing Applications," *Final Report, Jet Propulsion Laboratory Contract No. 950492*, December 15, 1964.
3. W. A. Pieczonka et al., "GaAs-Si Photon Activated Switch," to be published.
4. Latches with Type 1 drive transistors require lower external bias I_b and lower supply voltage V_{cc} than those with Type 2.

Received February 19, 1965.